# A suggested experiment to distinguish between the Bohmian Interpretation and the Standard Quantum Mechanics

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## Abstract

Based on the double-slit experiment of electrons, we suggest a proposal of thought experiment to distinguish between the Bohmian Interpretation (BI) and the Standard Quantum Mechanics (SQM). We mainly focus on the discussion of the meaning of the wave function (Schrödinger-$\psi$). The key technique is require to insert some slow-electrons or weak electron current into the space between the double-slit and the detector plane. We find that the two theories finally give out two totally different results about the affections which the externally inserted electrons cause to the original pattern of the interference fringes. Under the BI, the externally inserted electrons also can be influenced by the Quantum Potential (QP) in a totally same way with the electrons which come from the slits, so the positions they arrived at are preferred to certain bright zones, and the interference pattern will become more clearer. While under the SQM, the Schrödinger-$\psi$ does not represent an objectively real field, but only a mathematical construction of the probability characteristics of the particle itself, so the externally inserted electrons and the electrons which come from the slits have no correlations with each other. No any priority positions at the detector plane the externally inserted electrons will arrive. And the affections are only the addition of a uniform bright background. In such a meaning, the dark zones of the fringes of the interference pattern have been filled.

## 1. Introduction

As we all know, although Quantum Mechanics is one of the pillars of modern physics, the physical community have not formed a unified conceptual framework for understanding about the meaning behind the formulas. Controversies can be traced back to the beginning, while up to now.

In order to understand conflicts of the SQM with the classical system, in 1952, D. Bohm[1] suggested another interpretation using "hidden variables", which is occasionally coincided with L. de Broglie's pilot-wave theory[2].[1] Just as J. S. Bell[3] pointed out that there is nothing "hidden variables", the main meaning of the BI is that all variables are forced by the QP. According to the BI, the wave function represents a new kind of physically real field that is capable of exerting a force on the particle through its determination of the QP.

The BI enables one intuitively and imaginatively to understand how quantum process may actually come about. Maybe as D. Bohm[4] has realized that, the approach has not generally been adopted by the community of physicists, mainly because it did not lead to any new predictions for the actual experimental results. However, the indistinguishability with the SQM is not the inherent character of the BI. As is clearly stated in the beginning by D. Bohm, effects which caused by modifications of the suggested interpretation are insignificant in the atomic domain, but crucial importance in the domain of dimensions of the order of $10^{-13}$cm or less, where, the Copenhagen Interpretation of the Quantum Mechanics is totally inadequate.

Suggested experiments that can predict different results for the SQM and the BI have been the subject of many discussions in literatures over the years[5–11]. Here, we do not analyse and discuss these so many proposals, and just point out that there are at least three critical points one should especially pay attention to: (i) At dimensions of the order of $10^{-13}$cm or more, one may not give out a suggested proposal. At the state, the BI maybe

[1] In literatures, the two theories sometimes calls the de Broglie-Bohm pilot-wave theory (the dBB). However, since we mainly discuss the concept *the Quantum Potential* in Bohm's theory, and the dBB is not used here.

only provides a broader conceptual framework that servers as a basis for new or modified mathematical formulations for the description of physical system. (ii) Using the particle characteristics of a "photon" instead of classical real particles is not proper. According to the BI, light quanta are described as electromagnetic wave packets which have many particle-like properties. However, it would not be consistent to assume the existence of a "photon" particle, associated with each light quantum. (iii) The suggested experiment should be practically feasible to control and weakly dependent on energy and environment.

Considering the above attentions, in this paper we tentatively suggest a proposal of thought experiment to distinguish the two interpretations of Quantum Mechanics. Our suggested proposal is based on the double-slit experiment of electrons, which is famous as a deterministic experiment of its wave-like nature. What we want to distinguish is: Is the Schrödinger-$\psi$ a mathematical representation of an objectively real field in the BI Or a wave function only has the probability implication in the SQM which dose not represent as a real field?

## 2. The arrangement setup

The arrangement setup of our proposed thought experiment is not complicated (see FIG.1). The key technology is require to insert some slow electrons or weak electron current with the velocity in the positive $x$-direction into the space between the double-slit and the detector plane. These electrons which have low velocity in the positive $x$-direction come from the outside and do not from the source. We call them the externally-inserted-transverse-slow-electrons (abbreviated as the EITSE). Using the two interpretations, what we want to analysis is the affections which the EITSE will cause to the interference pattern formed by electrons from the source (if there does not exist the EITSE).

## 3. The BI predictions about the suggested experiment

Firstly, let's see what the result is in Bohm's theory. According to the BI on the double-slit experiment, the form of the QP between the double-slit and the detector plane pilots

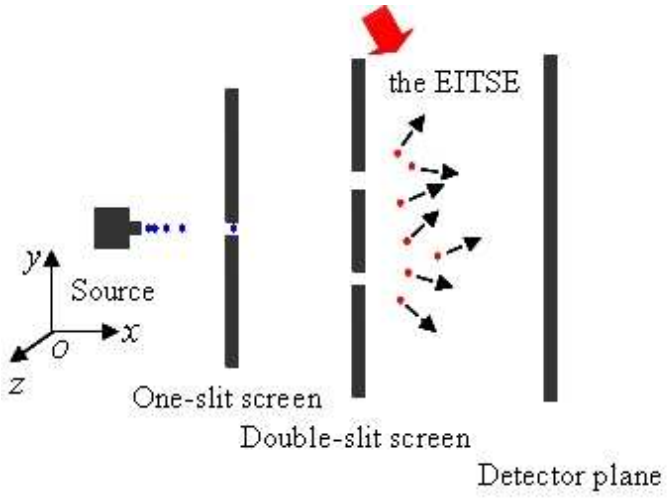


FIG. 1: Schematic Diagram of our proposed thought experiment. The red dots stand for the EITSE which have been inserted into the space between the double-slit and the detector plane. The blue dots stand for electrons emitted form the source which will traverse through the slits, and finally form a distribution of the interference pattern if there does not exist the EITSE.

the movement behaviors of electrons. The QP undergoes rapid and violent but harmonic fluctuations which appear a complex pattern of plateaus and valleys.[2] This directs a random distribution of incident particles to form fringes, ever far from the slits. We can make sure that the form of the QP also has strong influences on the EITSE instead of only on electrons come from the source[3], because in Bohm's theory the Schrödinger-$\psi$ represents an objectively real field and furtherly electrons should be indistinguishable for the QP. In a visual imagination, such a form of the QP is similar (but not identical) with "trapping wells" for the electrons which moving in this space wherever they come from. Since the form of the QP can pilot electrons which coming from the slits to form an interference pattern, there is no excuse that the QP does not pilot the EITSE in a same way to give out their contributions to the interference pattern. So we can sure that the interference pattern will

[2]The form is very reminiscent of the interference patterns of plane water waves.

[3]We call these electrons the source electrons, and abbreviate as the SE.

become more clear (see FIG.2(a)). The dark zones of the interference pattern also have the impossibility for the EITSE under the effects of the QP. Considering the individual behaviors of electrons which moving through the space between the double-slit and the detector plane, it's obviously that this is not in the domain of the atoms. On the other hand, in Bohm's theory fluctuations of the QP is under the order of $10^{-13}$cm or less.

The meaning of *slow electrons or weak electron current* is mainly based on the following expectations. (i) Theoretically, we hope the EITSE do not change the form of the QP which formed by the SE. This is reasonable because the QP of the EITSE does not undergo rapid and violent fluctuations, but is calm. Furthermore, when there is nothing the EITSE, the form of the QP has successfully piloted the SE to arrive at the bright zones despite the SE have high velocity and large energy. (ii) Such a setting guarantees that the EITSE and the SE will not vastly or directly interact with each other. (iii) Just considering the non-relativistic case is simple and enough. (iv) The arrangement should be practically feasible to control.

## 4. The SQM forecast and its differences with the BI predictions

Now, let's see what the result is in the SQM forecast. Based on a simple analysis, we can sure that the SE and the EITSE will not influence each other in any way. According to the Copenhagen Interpretation, the Schrödinger-$\psi$ describes the electron itself, while does not represent an objectively real field whose energy is distributed through space, but only a mathematical construction with the significance that the intensity in a given region is a measure for the probability that the particle is localized there. On the hand, the stochastically inserted EITSE have no correlations with the SE and further, there are no coherences between them. So the EITSE and the SE will do not affect (directly or indirectly) with each other.

If the distribution of the density of the EITSE is uniform in the positive $x$-direction, and the current is enough, it can be sure that the EITSE will make the original interference pattern of the SE becoming fuzzy. Under the original fringes, there will add a uniform

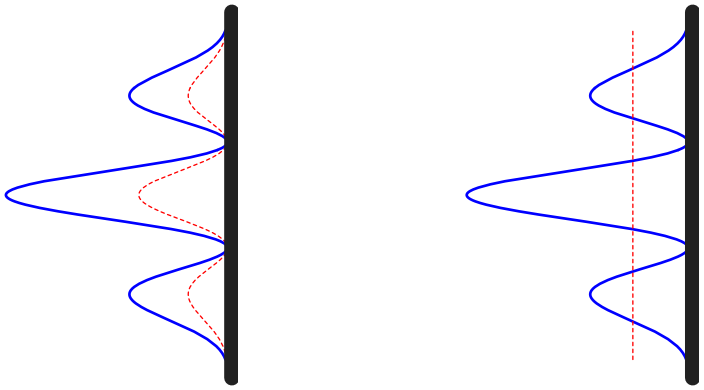


FIG. 2: (a)The result under the Bohmian Interpretation. (b)The result under the Copenhagen Interpretation. The blue solid and red dashed lines stand for distributions of density of electrons which from the source and the EITSE, respectively.

bright background formed by the EITSE. The dark zones of the original interference pattern will be filled by the bright background(see FIG.2(b)).

## 5. Conclusion and discussion

In this letter, we suggest a thought experiment in order to distinguish between the BI and the SQM. The thought experiment has mainly focused on the discussion of the meaning of the wave function Schrödinger-$\psi$.

With such a arrangement, the two interpretations finally give out two totally different results about the affections which the EITSE cause to the fringes of the interference pattern of the SE. In Bohm's theory, the EITSE also should be influenced by the QP in a totally same way with the SE. So the positions they arrive at are also preferred to certain bright zones. While in SQM, the Schrödinger-$\psi$ does not represent an objectively real field, but only a mathematical construction of the probability characteristics of the particle itself, so the EITSE and the SE have no correlations with each other. No any priority positions at the detector plane the EITSE will arrive. And the affections are only the addition of a uniform

bright background. In such a meaning, the dark zones of the fringes of the interference pattern have been filled.

In a same way, the setup of the arrangement can be based on the other experiments in similar equipment which reveal the wave-like features of the behavior of microscopic particles, such as diffraction experiments, and we do not described here detailedly. The microscopic particles also can be chosen as e.g., neutrons, protons and atoms.

By use of modern techniques, we have great confidence for the setup of our proposed arrangement of the thought experiment, because it feebly depends on energy and environment. The key technology is the realization of the EITSE. In addition, there is no other limitations, such as, the initial positions and momentum of the EITSE. However, the apparatus must also be ingeniously constructed.

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